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Technical Memorandum 26-76

AN INVESTIGATION OF COCKPIT LIGHTING FOR COMPATIBILITY WITH USE OF NIGHT-VISION GOGGLES, AN/PVS-5

Harry R. Stowell

July 1976
AMCMS Code 672716.11.H7000

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U. S. ARMY HUMAN ENGINEERING LABORATORY
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Memorandum 26-76
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): 6 AN INVESTIGATION OF COCKPIT LIGHTING FOR COMPATIBILITY WITH USE OF NIGHT-VISION GOGGLES, AN/PVS-5.
5. TYPE OF REPORT & PERIOD COVERED: 9 Final rpt.,
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): 10 Harry R. Stowell
8. CONTRACT OR GRANT NUMBER(s): 14 HEL-TM-26-76
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland 21005
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS Code 672716.11.H7000
11. CONTROLLING OFFICE NAME AND ADDRESS:
12. REPORT DATE: 11 Jul[redacted]76 12 21p.
13. NUMBER OF PAGES: 19
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Helicopters
Cockpit Lighting
Night-Vision Goggles
Human Factors Engineering

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Cockpit lighting in U. S. Army helicopters was investigated for compatibility with use of night-vision goggles, AN/PVS-5. Instrument-lighting systems in existing Army helicopters, e.g., eyebrow lighting, post lighting, are not suitable for use with night-vision goggles. A comparatively simple flood-lighting system can provide suitable lighting in the cockpit of existing helicopters for reading instruments with night-vision goggles. The most suitable instrument-lighting system for use with the goggles is integral instrument lighting; however, indicator lights need to be modified so they are compatible with the goggles. Methods were investigated for instantaneously refocussing the goggles inside the cockpit. Luminance levels compatible for use with night-vision goggles are stated in photometric terms.

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AMCMS Code 672716.11.H7000

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CONTENTS

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TABLES

AN INVESTIGATION OF COCKPIT LIGHTING FOR COMPATIBILITY WITH USE OF NIGHT-VISION GOGGLES, AN/PVS-5

INTRODUCTION

Instrument-lighting systems in existing Army helicopters, e.g., eyebrow lighting, post lighting, are not compatible for use with night-vision goggles, AN/PVS-5 (7). This type of instrument lighting is not uniform across instrument panels. Light reflected from instrument faces and surrounding surfaces, and even direct light from instruments' lamps, interferes both with reading instruments and with viewing outside the cockpit with the goggles (1).

Indicator lights, e.g., fire warning and master caution, produce hot spots or specular glare when viewed through the goggles. The legends on indicator lights are not legible, because glare from the lamp filament is visible with the goggles.

With the standard goggles, AN/PVS-5, it is impossible to refocus instantaneously for viewing inside the cockpit. Refocussing the goggles requires adjusting each lens independently, which normally requires two hands. The pilot needs a method to refocus the goggles instantaneously while he is operating flight controls. Providing suitable lighting in the cockpit is of small benefit if the pilot cannot read the displays because his goggles are out of focus.

Existing literature does not clearly define which displays the pilot must be able to see to fly nap-of-the-earth (NOE) safely at night. It may be assumed the pilot will want to see an undetermined number of instrument displays he may select while flying NOE at night.

The object in this investigation was to identify changes that are necessary to make present cockpit lighting compatible with using night-vision goggles (4). The information obtained here is also useful to insure that cockpit lighting in the Army's new-generation helicopters will be compatible with using night-vision goggles. Luminance values for use with the goggles are given in photometric terms. Various methods for instantaneously refocussing the goggles were investigated, and problems associated with each method were also identified and investigated.

METHOD

Equipment

Equipment and apparatus used in making the investigation included:

Photometric Measurement System, Gamma Scientific, Inc. (see Appendix for components of system).

Preliminary Instrument-Panel Lighting Mock-Up.

UH1-D Instrument-Panel Lighting Mock-Up.

Sperry Instrument Panel, Optimum Lighting-System Mock-Up.

Night-Vision Goggles, AN/PVS-5

Digital Multimeter

Regulated Power Supplies, 28VDC and 28VAC

Preliminary Investigation

A panel was fabricated to simulate the instrument panel in a single-pilot cockpit similar to the AH1-G COBRA. Instrument dial faces without cover glass were mounted on a panel (Figure 1). Flood lamps were built to distribute light uniformly across the panel. Voltage to these flood lamps was 28VDC, variable from zero volts to rated lamp voltage. Provisions were made to install color filters on the flood lamps. The panel was located in a dark environmental trailer for testing.

Eight subjects were selected to read instruments while wearing the night-vision goggles. All subjects except one were experienced in flying, ranging from private pilot to rated military pilot. Subjects ranged in age from 24 to 55, with a mean age of 37. Each subject was partially dark adapted in a dark room for 15 minutes before taking a reading test on the panel. After being seated in front of the panel (28-inch eye-to-panel distance), and wearing the goggles, the subject was instructed to increase the lamp voltage until he could read the instrument-scale markings easily. The process was repeated for individual subjects. Lamp voltage was recorded on a digital multimeter.

Photometric measurements were taken on instrument markings at the lamp voltages recorded. Luminance measurements ranged from 1.5×10^{-5} to 2×10^{-5} foot lamberts. Variations in the light-level settings were caused by the sensitivity of lamp-voltage adjustment, and the broad response of the automatic-gain feature on the night-vision goggles.

A blue filter (400NM) and a red filter (620NM) were tested on the flood lamps to assess how monochromatic light affected the goggles. When the luminance measurements were corrected photopic and compared, both filters gave comparable luminance levels with use of the goggles.

UH1-D Instrument Panel

A UH1-D instrument panel recovered from salvage was cleaned and painted with Nextel Black Velvet Coating, product no. 101-C10. The instruments were original equipment on the UH1-D instrument panel. Glass faces were plain cover glass without any anti-reflection coating. Some instruments had markings in fluorescent paint, while others had plain white markings. The instrument panel was mounted on a mocked-up side-by-side seating arrangement in the dark environmental trailer (Fig. 2). A 28VDC regulated power supply was used to power the lamps. The room's ambient light (1×10^{-7} foot candles) was measured with all lights off.

The secondary lights (MS21627-1) on the instrument panel (4 ea), were modified to improve luminance distribution across the panel (Fig. 3). A layer of white translucent material was applied underneath the red (IPL) filter to diffuse the light, thus preventing spot reflections on instrument cover glasses. A light control was installed on the center console to vary lamp voltage between zero and 28VDC. Secondary lamps under the panel's glare shield were not moved from their original locations.

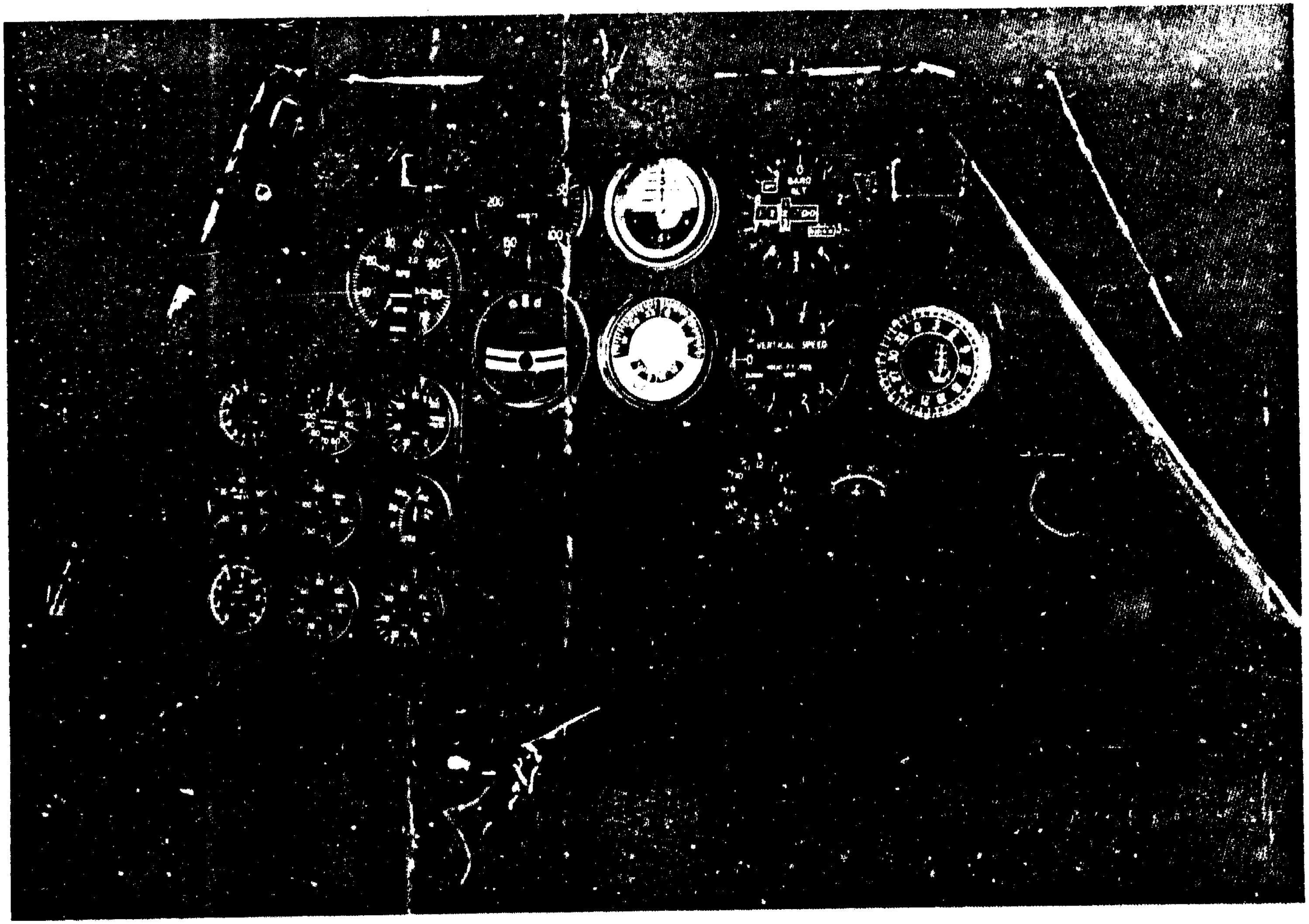


Fig. 1. Experimental instrument-panel lighting mock-up
(flood lighting)

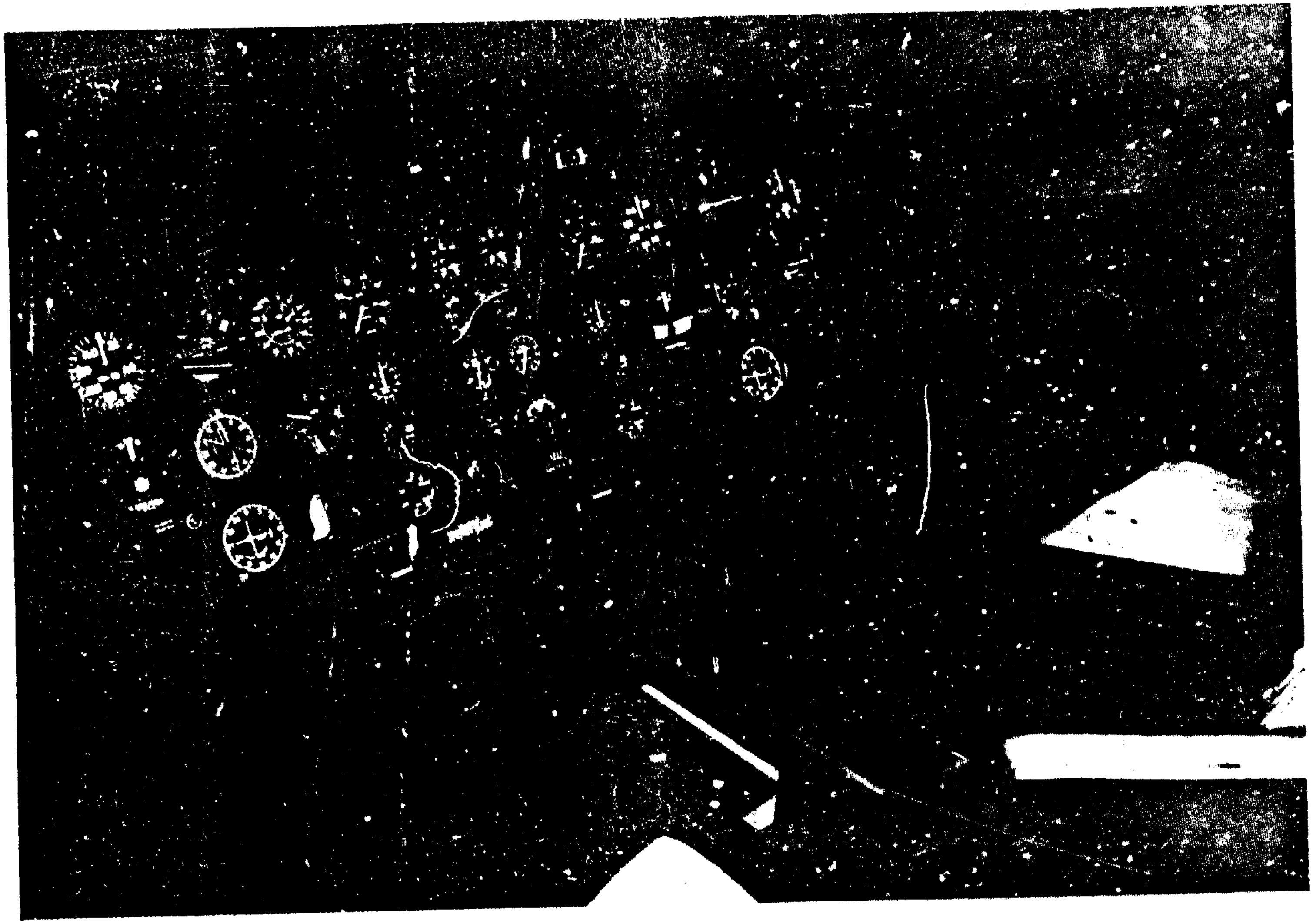
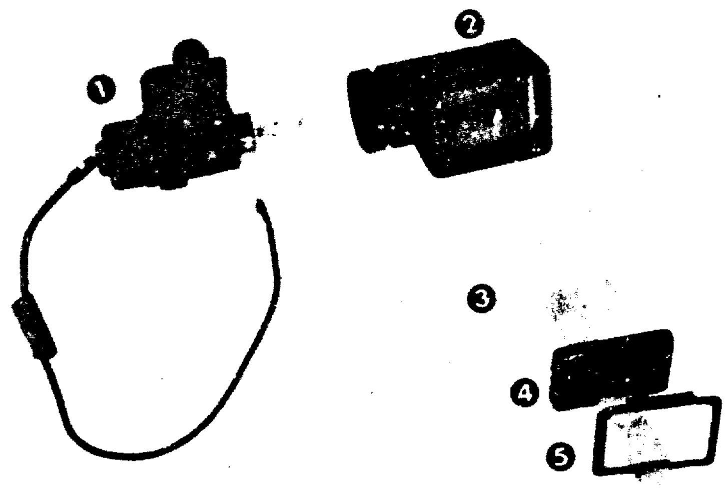


Fig. 2. UH1-D instrument-panel lighting mock-up
(flood lighting)



1. Mounting Bracket and Bulb
2. Lamp Housing
3. *White Translucent Material
4. Red (IPL) Filter
5. Retainer Ring

*Added for use with NVG.

Fig. 3. Secondary light assembly MS 25027-1, modified for use with NVG

The brightness of these secondary lamps was adjusted to determine the minimum luminance level that allowed subjects to read instruments legibly with the goggles. The voltage measured at the lamps was 4.5 volts. Photometric measurements then assessed the brightness of instrument markings at the normal eye position, 28 inches is in front of the panel (Table 1).

TABLE 1

Photometric Measures of Instrument Markings on UH1-D Panel Lighting Mock-up, with Modified Secondary Lighting System at Brightness Setting for Use with Night-Vision Goggles (NVG's)(AN/PVS-5)

Cover Glass	Color Light	Lamp Volt (DC)	Loc. on Panel	Lum. of Markings (Ft L)	Room Amb (Ft C)
Plain	Red (IPL)	4.5	Center	1.8×10^{-5}	1×10^{-7}
Coated (HEA)	Red (IPL)	4.5	Center	2.5×10^{-5}	1×10^{-7}
No Glass	Red (IPL)	4.5	Center	3.5×10^{-5}	1×10^{-7}
No Glass	Red (IPL)	4.5	Bottom	1.5×10^{-5}	1×10^{-7}
No Glass	Blue (400NM)	4.5	Center	5×10^{-6}	1×10^{-7}

Photometric measurements were also made to find the brightness of instrument markings with the cover glass removed, and with the cover glass coated with reflection-reducing coating (HEA) MIL-C-14806 (2). The same instrument and the same marking was used to take luminance measurements with cover glass and without cover glass. Lamp voltage was maintained at 4.5V. Reflection-reducing cover glass (HEA) yielded a higher luminance value than the plain cover glass. (5, 6, 8) The highest luminance value was expected with cover glass removed from instrument faces (Table 1).

Voltage at the lamps require adjustment depending on density of filters and the type of lamp bulb used. However, luminance on markings should be a minimum of 2×10^{-5} foot lamberts for pilots to read instruments legibly. Plain white markings on instrument dial faces provide more efficient reflecting surfaces, and are expected to improve legibility over the fluorescent-type markings.

Luminance values will be a little dimmer for instruments at the bottom of the panel, depending on the panel's overall height. A value of 1.8×10^{-5} foot lamberts was obtained with instruments centered between top and bottom of the panel.

The modified secondary lamp's illuminance and luminance characteristics were measured photometrically at the level used with the goggles (Table 2). Lamp brightness was also measured photometrically at rated voltage (28 VDC). At full brightness, the modified lamps produced 163 foot lamberts with the red (IPL) filter, a satisfactory level for reading instruments with unaided vision.

Indicator Lights, Fire Warning/Master Caution

It was necessary to modify the indicator lights (fire warning and master caution) to obtain uniform distribution of light across the face of the indicators.

TABLE 2

Photometric Measures of Modified Secondary Lamps at Minimum Luminance for use with NVG's, and at Maximum Luminance

Color Light	Lamp Volt. (DC)	Lum. (Ft L)	Illum. (Ft C)
Red (IPL)	4.5	9.5×10^{-3}	1.45×10^{-3}
Red (IPL)	28.0	163	—

Existing indicator lights used on the UH1-D panel, produce glare when viewed with the goggles, because direct light from the lamp filaments can be seen through the goggles. A white coating, almost opaque, was applied on the end of each lamp. This coating, which is 5/32 inch in diameter, blocks the lamp's filament from direct view. A white translucent material was also placed under the color filter to diffuse the light for more uniform light distribution across the face of the indicators (Fig. 4).

After the secondary lamps had been adjusted to yield 1.8×10^{-5} foot-lambert luminance on the instrument markings, the indicator-light voltage was adjusted to give a light level easily discernable with the goggles. Voltage to the fire-warning indicator was 4.5 VDC, while voltage to the master-caution indicator was 4.2 VDC. Increasing the voltage above these values washed out the legends so they were no longer legible with the goggles.

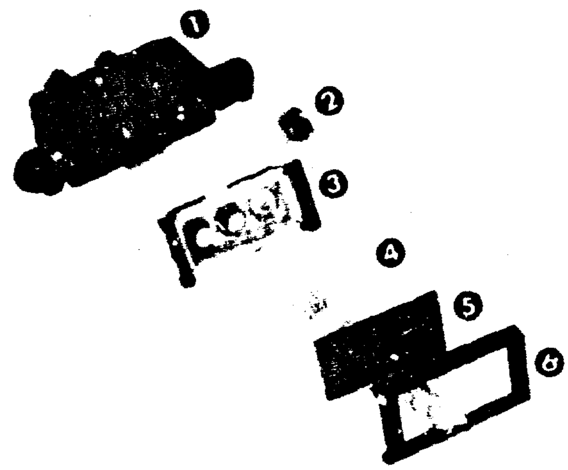
Brightness on the face of the indicator lights (fire warning and master caution) was measured photometrically (Table 3). Brightness values were the same (8×10^{-5} foot lamberts) for both indicators.

TABLE 3

Photometric Measures of Modified Indicator Lights at Minimum Brightness Setting for Use with NVG's, and at Maximum Brightness for Unaided Vision

Indicator Lights	Lamp Voltage (DC)	Luminance (Ft L)
Fire Warning	4.5	8×10^{-5}
Master Caution	4.2	8×10^{-5}
Fire Warning	28.0	150
Master Caution	28.0	85

Brightness of the indicators was also measured photometrically at the full rated lamp voltage of 28 VDC (Table 3). At full voltage, the master-caution indicator light was dimmer than the fire-warning indicator light. This may be attributed to the light-transmission characteristics of the yellow filter used on the master-caution indicator. However, the high brightness level of both indicator lights was satisfactory both for viewing at night with unaided vision, and for viewing under daylight conditions.



1. Indicator Housing
2. *Bulb Coated on Tip (white opaque coating)
3. Bulb Retainer
4. *White Translucent Material
5. Legend and Red (IPL) Filter
6. Retainer Ring

*Added or modified for use with NVG.

Fig. 4. Indicator light fire warning, modified for use with NVG.

Light flux produced by the UH1-D panel, when illuminated for use with the goggles, was measured photometrically (Table 4). Measurements were taken at the eye position, assuming a 28-inch panel distance. The ambient light with panel lights out was 1×10^{-7} foot candles.

TABLE 4

Photometric Measures of Illuminance Reaching the Eye Position, with UH1-D Panel Illuminated for Use with NVG's

Lighting	Lamp Voltage (D.C.)	Illuminance at Eye Position (Ft C)
Room Ambient	No Lights	1×10^{-7}
Secondary Lights & Indicator Lights	4.5	2.5×10^{-6}
Secondary Lights Only	4.5	1.2×10^{-6}
Fire Warning & Master Cation Indicator Lights	4.5 4.2	1.3×10^{-6}
Fire Warning	4.5	7×10^{-7}
Master Caution	4.2	5×10^{-7}

Light at the exit pupil, looking through goggles at the lighted panel, was also photometrically measured (Table 5). Indicator lights (fire warning and master caution) were turned off for these measurements. Based on the photometric data, exposure to light in the eyepiece of the goggles is comparable with looking outside under moonlight conditions with unaided vision.

TABLE 5

Photometric Measures of Light with NVG's at the Exit Pupil, with Light Level for Use with NVG's

Panel	Lamp Volt	Color Light	Lum. (Ft L)	Illum. (Ft C)
Sperry (Integ. Light.)	6.3 AC	White	1.3×10^{-2}	3×10^{-3}
UH1-D (Flood Light.)	4.5 DC	Red (IPL)	1.3×10^{-2}	3×10^{-3}

Thus the advantage of dark adaptation is degraded somewhat by viewing with the goggles (1). However, the effect on dark adaptation is no worse than viewing outside under moonlight condition with unaided vision. When ambient illumination is dimmer than moonlight it is doubtful that aviators could see sufficient detail on the ground to accomplish a landing with any degree of safety, even with the advantage of complete adaptation

While viewing the UH1-D instrument panel with night-vision goggles, ambient light was varied from 1×10^{-7} to 5×10^{-2} foot lamberts. This was done mainly to examine how night ambient light affects instrument reading with goggles. Legibility of instruments appeared to improve with increasing ambient light. Brighter ambient light from outside appeared to improve instrument legibility. With brighter ambient light outside, the instrument panel also became less distracting with the goggles adjusted at infinity.

The background surfaces of the UH1-D instrument panel were illuminated by the flood lights, and they were visible with the goggles. Even after applying Nextel Black Velvet paint to the panel surface, reflected light against the dark background was still visible with the goggles. Limitations of the photometric system prevented measuring the brightness of the dark background at the low luminance (1×10^{-6} foot lamberts or lower).

Sperry Instrument-Panel Optimum Lighting System (Fig. 5).

The Sperry instrument-panel lighting mock-up was developed on a contract from U.S. Army Aviation System Command (AVSCOM) to Sperry Corp. to improve the design of instrument-panel lighting for Army helicopters. Sperry optimized the instrument lighting on this instrument panel before delivering it to the U.S. Army Human Engineering Laboratory (HEL) for additional evaluation. This investigation compared the integral lighting system on the Sperry panel with flood lighting for use with night-vision goggles. The integral instrument lighting on the Sperry panel was clear (tungsten) white lighting. Several instruments separate from the instruments on the lighting mock-up panel, were modified to red IPL integral lighting for light measurements. As with the UH1-D mock-up, voltage on the Sperry panel was adjusted to the lowest luminance level at which instrument readings were legible. The red (IPL) mock-up instruments were tested in a similar manner to compare their luminance levels. Voltage recorded for the white-lighted instruments was 0.63 VAC, as compared to 0.85 VAC for the red (IPL) lighted instruments.

Photometric measurements were taken on instrument markings (Table 6). The room's ambient light level with all lights out was 1×10^{-7} foot candles.

TABLE 6

Photometric Measures of Instrument Markings on Sperry Panel-Lighting Mock-up, at Brightness Setting for Use with NVG's

Cover Glass	Color Light	Lamp Volt (AC)	Loc. on Pan.	Lum (Ft L)	Illum. at Eye Pos. (Ft C)
Coated (HEA)	White	0.63	Any point on Panel	1.5×10^{-5}	5×10^{-7}
Coated (HEA)	Red (IPL)	0.85	Any point on Panel	1.5×10^{-5}	5×10^{-7}

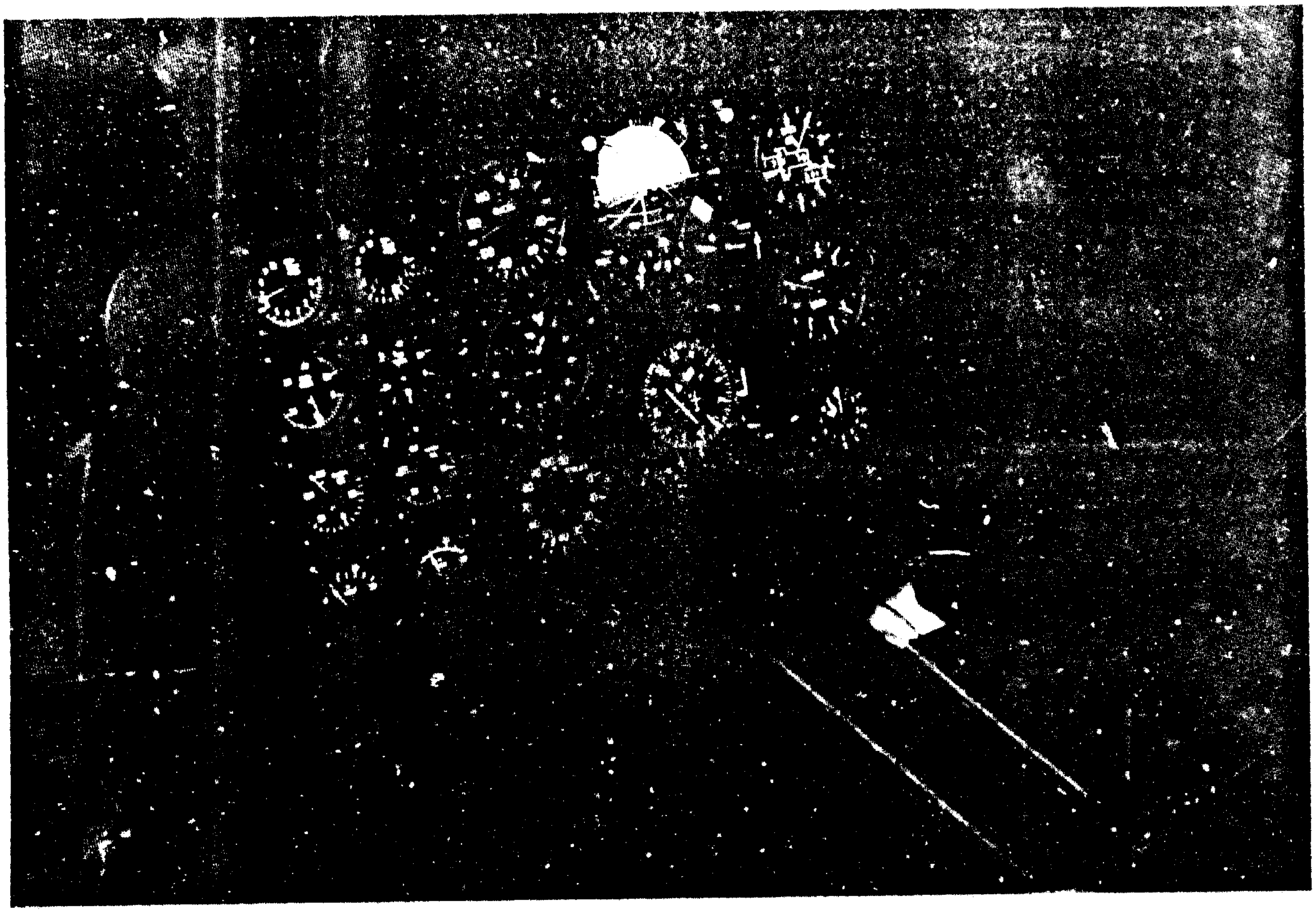


Fig. 5. Sperry instrument panel lighting mock-up
(integral lighting)

Photopically corrected photometric measurements yielded equivalent luminance values (1.5 x 10^{-5} foot lamberts) for red (IPL) lighting and clear (tungsten) white lighting. Higher voltage (35) was required to compensate for red (IPL) instrument lighting. The light flux (5 x 10^{-7} foot candles) measured at the eye position (28-inch panel distance) was lower than with flood lighting on the UH1-D panel. The background surface of the Sperry panel was not visible with the goggles. Luminance on instrument markings appeared uniform across the panel. Instruments on the Sperry panel were balanced with individual trim pots to assure uniform luminance(3). This accounts for slightly lower luminance (1.5 x 10^{-5} foot lamberts) than on the UH1-D panel for comparable instrument legibility. The Sperry panel was already coated with Nextel Velvet Black paint. Observers wearing goggles noted that the surrounding area in the mock-up cockpit produced noticably less visible light with the Sperry panel than with the UH1-D panel. This finding indicates that integrally illuminated instruments reduce reflected light.

Map Reading

Map-reading tests with night-vision goggles used both experimental black maps and standard maps with a scale of 1:25,000. Both types of maps depicted the same area. Only major marks (large figures and letters, major roads and rivers, and lakes) were legible with the goggles. Minor elevation figures and minor contour lines could not be seen clearly with the goggies on either type of map. Resolution on the standard map was not so good as on the experimental black map. The standard map's light background produced a washout effect with the goggles. Some experimentation was done using fluorescent ink and ultraviolet light on markings for reading with the goggles. This method of marking maps would improve legibility. However, resolution characteristics of the goggles themselves must be improved to insure that small marks are clearly legible (1). The night-vision goggles, AN/PVS-5, used in this experiment seemed to have relatively poor resolution characteristics. It is not known how closely the characteristics of these goggles approximate those of standard production goggles.

Night-Vision Goggles, AN/PVS-5

The present awkward method for refocussing night-vision goggles for viewing in the cockpit must be improved. Refocussing the goggles requires the pilot to adjust the lens piece manually.

The study examined several ways to simplify refocussing the goggles for viewing in the cockpit. Aperture sharing was considered, because this method would not require an adjustment of the lens to view inside the cockpit. The aperture-sharing technique places a blocking filter in front of the lens; this filter will accept light with wavelengths longer than 500nm, but rejects shorter wavelengths of light. A small aperture in the center of the filter allows wavelengths shorter than 500mm to pass. If the aperture in the center of the lens is small, it should not interfere with viewing outside. However, the displays in the cockpit must be illuminated with wavelengths shorter than 500nm.

Different sizes of apertures were used to change the goggles' depth of field for reading instrument displays. The aperture openings were applied to the center of the blocking filter, with the goggles adjusted at infinity for viewing outside the cockpit. The best aperture size for reading instrument displays was 1.5mm diameter; this size of aperture made it possible to read instruments without refocussing the goggles. However, it was observed that the light level must be increased 500 times for viewing thru the aperture, as compared to viewing with the lens wide open The source's wave length has little or no effect on the light level when equivalent photopic correction is applied.

Instrument reading with aperture sharing appeared satisfactory under low ambient light, 1×10^{-7} foot lamberts. The 1.5mm-diameter aperture did not interfere with outside viewing when the goggles were focussed at infinity. However, when the instrument panel was exposed to night ambient light, it cancelled the effects of the blue filter on instrument lights (490nm), because longer wavelengths of light were reflected onto the instrument panel. Displays then became visible through the lens' blocking filter, and made it impossible to read instruments through the aperture.

Another approach to refocussing the goggles in the cockpit was placing lenses of various focal lengths in front of the goggle lens. Each lens was fitted with an adapter that could be mounted to the goggles' lens. The lens could be lifted to permit viewing at infinity with the goggles (Fig. 6). Best results were obtained using two lenses as with different focal lengths, 24 inches and 16 inches. This combination accommodated a range of eye-to-panel distances. Some observers were not immediately aware the lenses had different focal lengths. This approach to refocussing in the cockpit gave the same results as manually adjusting the goggle lens, except that the user can refocus instantaneously by simply moving the lens adapter into place. This technique, if automated by some electronic device, operable by a switch on the pilot's control, appears to be a reasonable solution to instantaneously refocussing the AN/PVS-5 goggles in the cockpit.

DISCUSSION

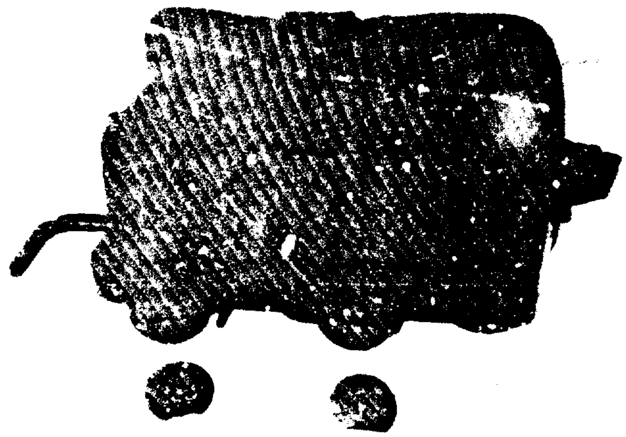
Cockpit lighting in existing Army helicopters can be made compatible for use with the night-vision goggles, AN/PVS-5, with minor modifications to the secondary flood-lighting system and to the indicator lights. Secondary lights used in the UH1-D (MS21627-1) are readily available and can be modified and mounted in any helicopter. The standard indicator lights, fire warning and master caution, may also be readily modified in any type of helicopter.

An adjustable control suitable for low-voltage adjustment may be required, or a switch may be installed to provide a fixed luminance for the secondary lighting. A variable light control adjustable down to very low voltage is preferable to a fixed setting. This would allow individuals to adjust the light level to accommodate their particular visual requirements.

Indicator lights should be provided with a switch to reduce the light level for use with goggles. However, the indicator-light circuiting must reset the light level to normal brightness for the unaided eye when the instrument lighting is energized.

If the lighting system in the new-generation helicopters is integral lighting with uniform light distribution across instruments on the panel, the lighting will probably be compatible with using the goggles (3). The instrument-light adjustment must be capable of fine voltage adjustment in the low range. Flood lights as described in this report can be incorporated for compatibility with the goggles. Flood lighting has the advantage of illuminating controls that otherwise are not visible with intergral instrument lighting.

The method of refocussing on the night-vision goggles, AN/PVS-5, must be improved for compatibility in helicopter cockpits. Automated selection of fixed-focus lenses appears to be necessary in solving the refocus problem.



1. AN/PVS-5
2. Lens and Adapter
3. Aperture 1.5mm Diameter

Fig. 6. Night vision goggles AN/PVS-5, with fixed lens and adapter and aperture 1.5mm diameter used to focus inside the cockpit.

If night-vision goggles are to be used for map reading, contrast between map markings must be improved. A solution to this problem may be using fluorescent ink with ultraviolet lighting, and increasing the size of figures representing terrain elevations and contour lines. This method, using fluorescent ink, would also improve map legibility with unaided vision. Goggles with improved resolution would probably help solve the problem of marking sizes.

Light reflections must be kept to an absolute minimum in the cockpit area when night-vision goggles will be used (6). Wherever possible, surfaces not required to be visible should be coated with suitable non-reflective material.

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APPENDIX

PHOTOMETRIC EQUIPMENT

Photometric measures were taken with a Gamma Scientific, Inc., photometric system in a dark environmental trailer. The system includes the following equipment:

a. Photometer, Model 2020

b. Photometer, Digital, Model 820A

c. High-Efficiency Photometer Telescope, Model 2020-31

d. Cosine Receptor, Model 2020-1A

e. Telephotometer, Model 2000

f. Photometric Microscope, Model 700-10-2B

g. Luminance Standard, Model 220-I

h. Neutral-Density Filters

All illuminance and luminance measurements were photopically corrected.